

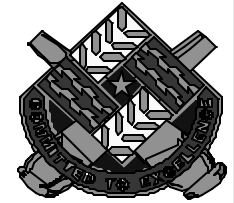
US Army TACOM-TARDEC Intelligent Mobility Program

***Dr. Jim Overholt
Senior Research Scientist
US Army Tank Automotive RDE Center (TARDEC)
Warren, MI 48397-5000
overholj@tacom.army.mil***

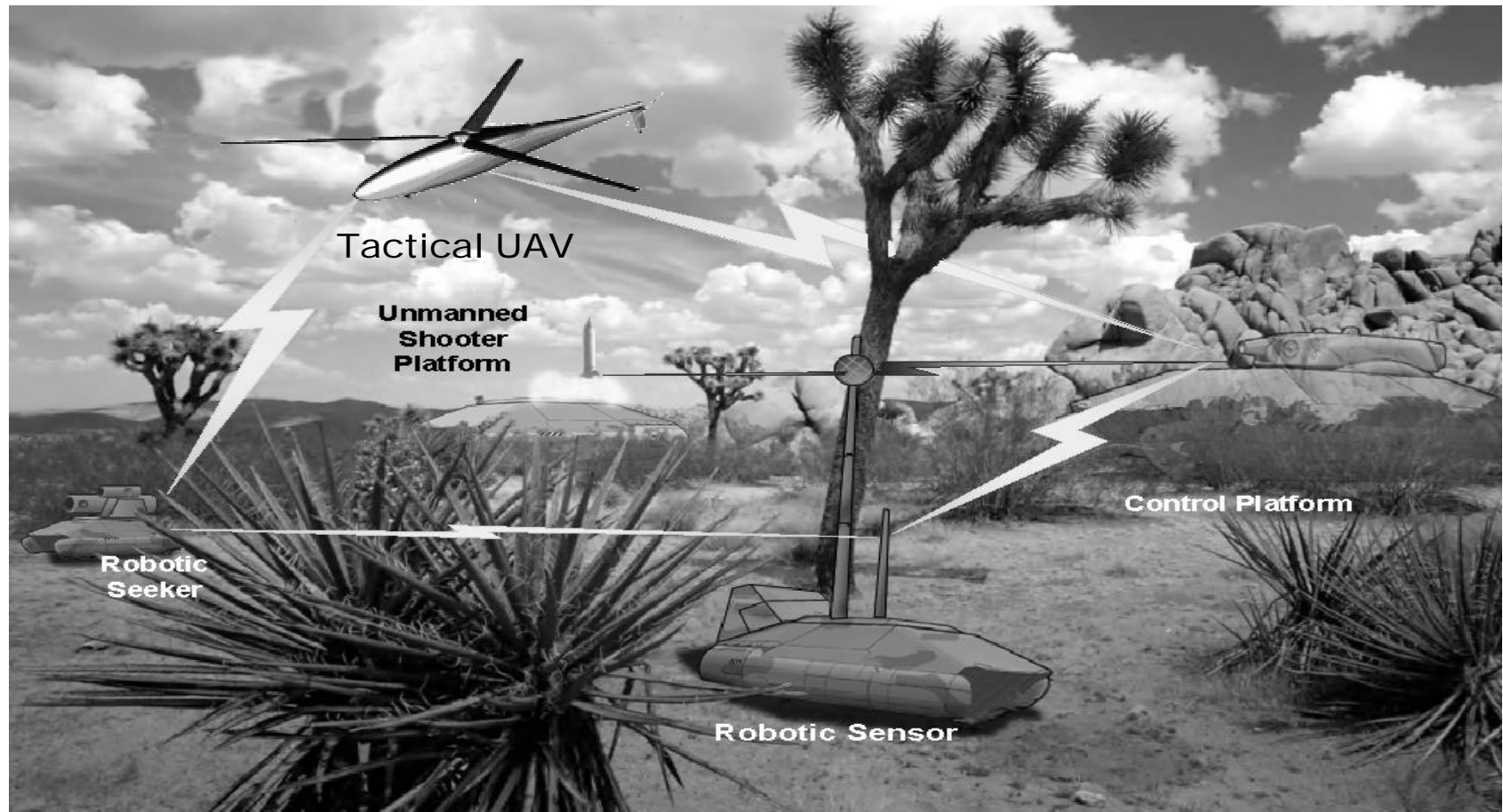
Tank-automotive & Armaments COMmand

Report Documentation Page

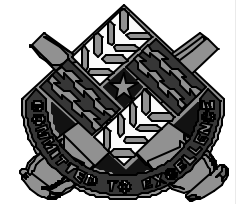
Report Date 29May2001	Report Type N/A	Dates Covered (from... to) -
Title and Subtitle US Army TACOM-TARDEC Intelligent Mobility Program	Contract Number	
	Grant Number	
	Program Element Number	
Author(s) Overholt, Jim	Project Number	
	Task Number	
	Work Unit Number	
Performing Organization Name(s) and Address(es) US Army Tank Automotive RDE Center (TARDEC) Warren, MI 48397-5000	Performing Organization Report Number	
Sponsoring/Monitoring Agency Name(s) and Address(es) NDIA (National Defense Industrial Association) 211 Wilson Blvd, STE. 400 Arlington, VA 22201-3061	Sponsor/Monitor's Acronym(s)	
	Sponsor/Monitor's Report Number(s)	
Distribution/Availability Statement Approved for public release, distribution unlimited		
Supplementary Notes Proceedings from the 2001 Vehicle Technologies Symposium - Intelligent Systems for the Objective Force, 29-31 May 2001 Sponsored by NDIA		
Abstract		
Subject Terms		
Report Classification unclassified	Classification of this page unclassified	
Classification of Abstract unclassified	Limitation of Abstract UU	
Number of Pages 18		



Robotics "Vision" for FCS



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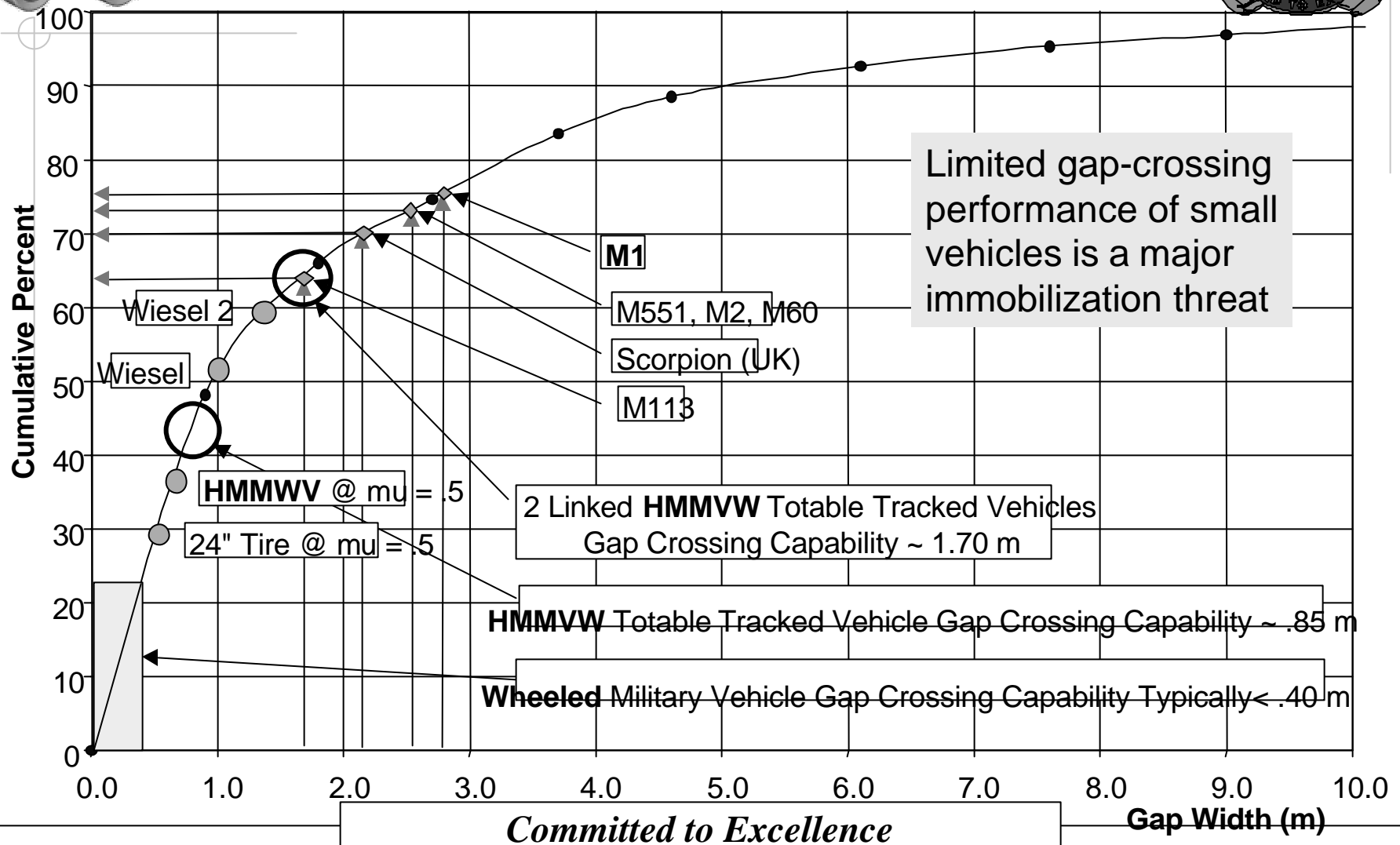
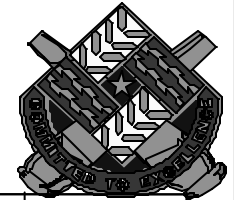
UGV Mobility Issues

Issues	Manned System	Unmanned System
Human Factors:		
• Absorbed Power	• 6 watts (driver seat)	• ± 30 g electronics
• Rollover	• No rollover / injury	• Self righting—operable
• Crash	• No crash / injury	• Crash tolerant—operable
• Mine	• No mine encounter	• Absorb blast—operable
• Hit Risk	• Minimize	• Absorb hit—operable
Net Mobility Effect	<ul style="list-style-type: none">• Reduced cross country speed• Complex suspension• Limited route availability	<ul style="list-style-type: none">Higher cross country speedSimpler suspension• Higher payload fraction• Lower CostBetter Trafficability• No personnel risk

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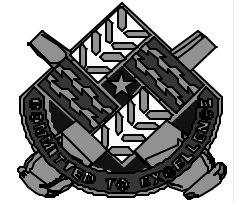


Gap Crossing Capability in Germany



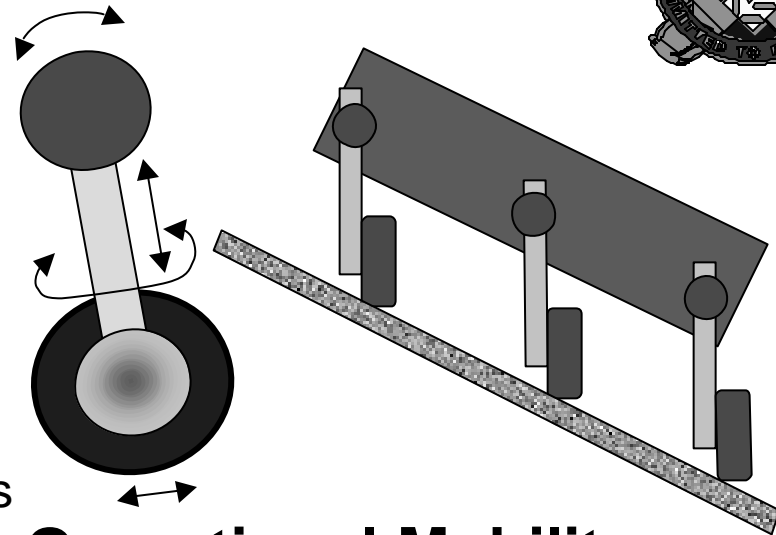
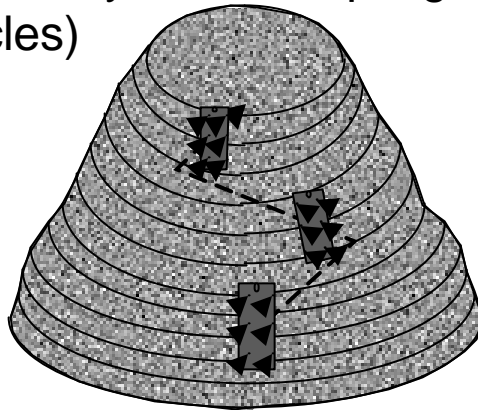


What Is Intelligent Mobility?



Inherent/Intrinsic Mobility

- Basic physical capability
- Ability to adjust the configuration and performance characteristics
- Governs the vehicle to execute commanded maneuvers and trajectories
- Advanced running gear, drive, control technologies and dynamic coupling (tandem vehicles)



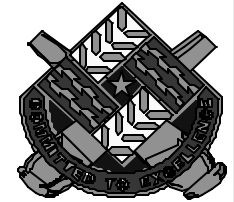
Operational Mobility

- Applied mobility
- Governs and directs inherent mobility
- Selects the driving mode and route/velocity trajectory
- Advanced trajectory planning, navigation, learning and reactive behaviors

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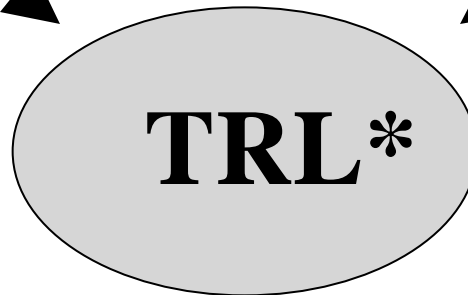


Intelligent Mobility Program



**Ft. Benning
Ft. Knox
Ft. Leonard Wood**

**Tyndall AFRL
SPA WAR Navy
JPO Army**



**Direct tech transition from
R&D to the user community**

**Support to tri-service
organizations & the
Battlelabs**

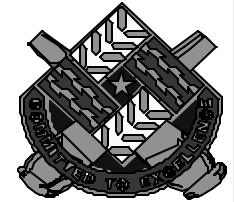
***TRL - TARDEC Robotics Laboratory**

Mix of research & customer funding

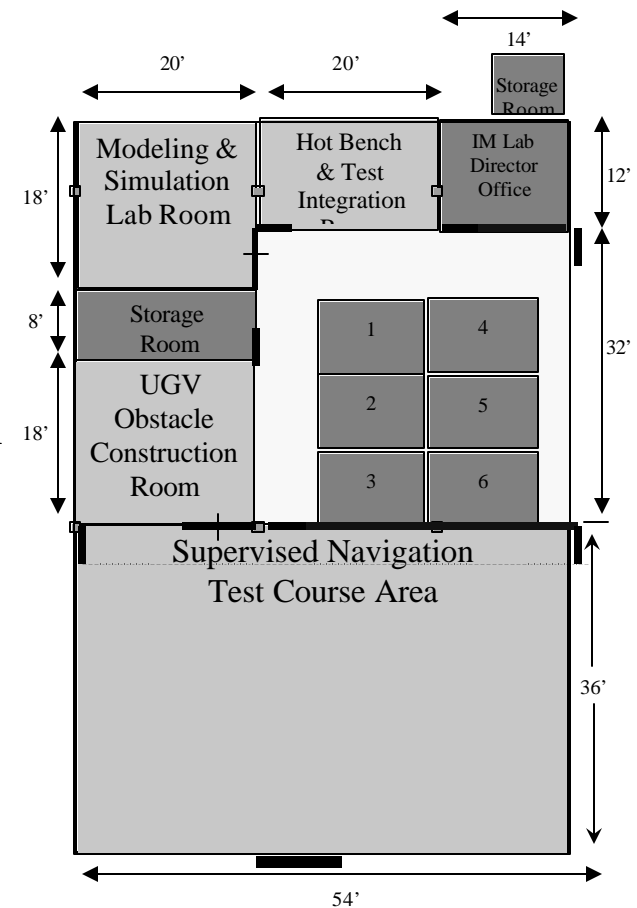
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TRL Facilities



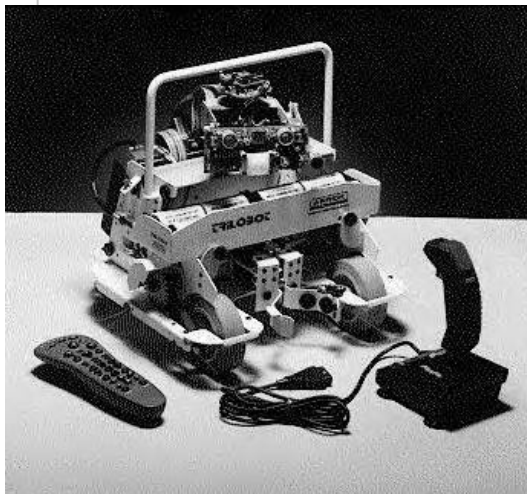
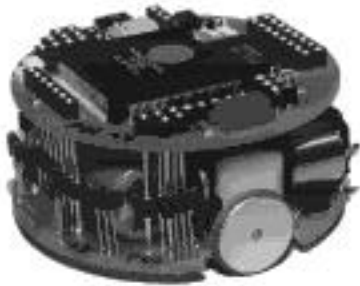
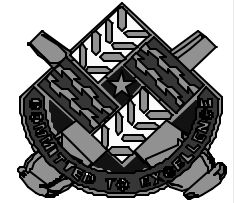
- ◆ Office Space for 10 personnel
- ◆ Behavioral Robotics lab
- ◆ Electronics integration room
- ◆ Modeling and simulation room
- ◆ Hardware room
- ◆ T&E bay for robots



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Behavioral & Evolutionary Robotics Lab



- ◆ Creation of varying fidelity models of robots and sensors.
- ◆ Development of behavior-based navigation, mapping schemes.
- ◆ Transition to lab hardware and progressively larger, more complex robots (e.g predict performance).
- ◆ Development of Evolutionary Algorithms for tuning and improving robot performance.
- ◆ Evolve the controllers in simulation.
- ◆ Transition to robots to finish the job.

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Modeling & Simulation Lab



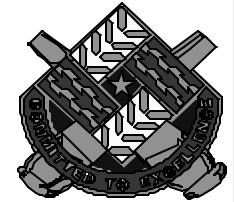
- Perform mobility simulations
- Perform model validations
- Drive any hardware-in-the-loop bench testing
- Assist NRMM upgrade?
- Wargaming scenarios
- Conduct “virtual” interactions with MOUT facilities via RAVENS



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RAVENS



RAVENS: Geographically distributed Soldier/Marine in-the-loop, Hardware in-the-loop, Software in-the-loop virtual & live analysis, test, & experiment architecture



- Assist Users in Requirements Development Efforts
- Assist the S&T community in Developing & Evaluating Technologies
- Assist in Risk Reduction Efforts
- Assist in Developmental and Operational Tests

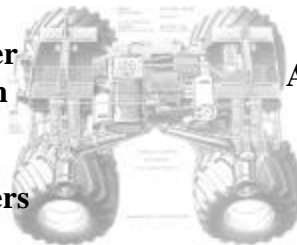
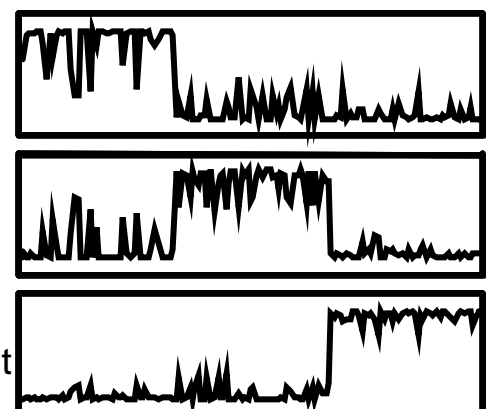
Vision - Applying SBA/SMART principles to minimize cost, speed development, reduce risk, & ensure that Soldiers and Marines remain at the center of all system development efforts

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Terrain Classification Sub-System

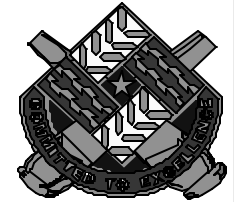


<p><u>Objective & Approach</u></p> <ul style="list-style-type: none"> - Generic, low-cost, light-weight, low power sensor package to sense vehicle dynamics and terrain properties - Machine learning algorithm to classify terrain type from sensor data 	<p><u>FY 01 Milestones</u></p> <ul style="list-style-type: none"> - Demonstrate prototype system - Evaluate on 6 terrain types
<p>3 DOF Inclinometer</p> <p>3 DOF Gyro</p> <p>Linear Encoder on Suspension</p> <p>Wheel Encoders</p> <p>Capacitance Sensor</p> <p>Ultra-Sonic Sensor (active)</p> <p>Linear Accelerometer</p> <p>Microphone</p> <p>Current & Voltage Sensors</p> 	<p><u>Neural Net Classifier (single sensor)</u></p> <p>Grass</p> <p>Gravel</p> <p>Pavement</p> 

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Negative Obstacle Detection System



Objective

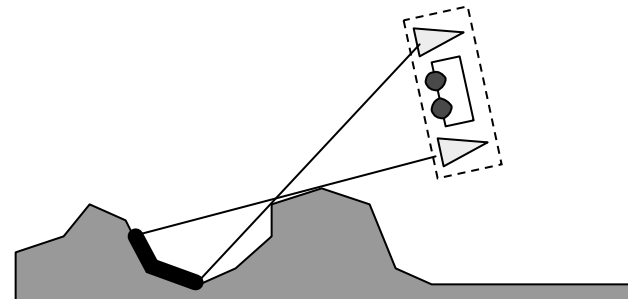
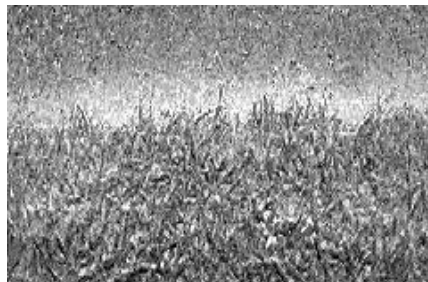
- Navigation vision system integrating multi-source projected light and trinocular stereo vision
- Downstream SWIR system in 1.8 to 2.0 micron CO₂ absorbing “dark band”

FY 01 Milestones

- Demonstrate prototype system
- Evaluate as a function of obstacle
 - Size
 - Distance
 - Terrain cover

Shadows isolation locates negative features from over-lit and under-lit images.

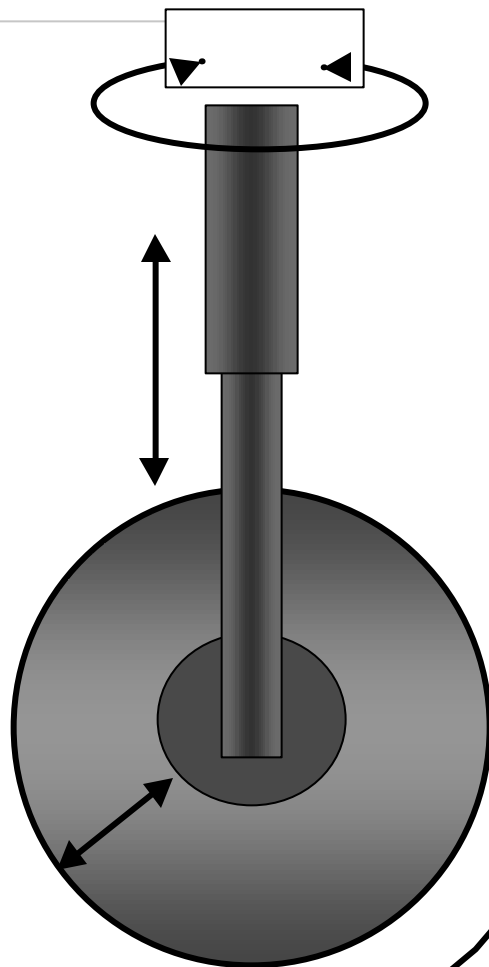
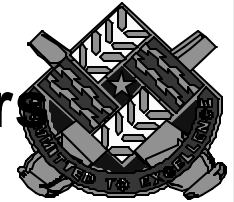
Vertical-offset stereo cameras provide range to horizontal shadows.



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Intelligent Wheel Module: Embedded Sensors, Controllers and Actuator



Sensors measure forces and response

- Wheel spin rate and drive torque
- Vertical strain, rate and position
- Twist strain, rate and position
- Tire pressure

Automatic controllers optimize mobility

- Minimize slip during acceleration, braking, steering and side slope traverse
- Minimize rolling resistance during on-road travel
- Minimize shock and vibration transmitted into the chassis

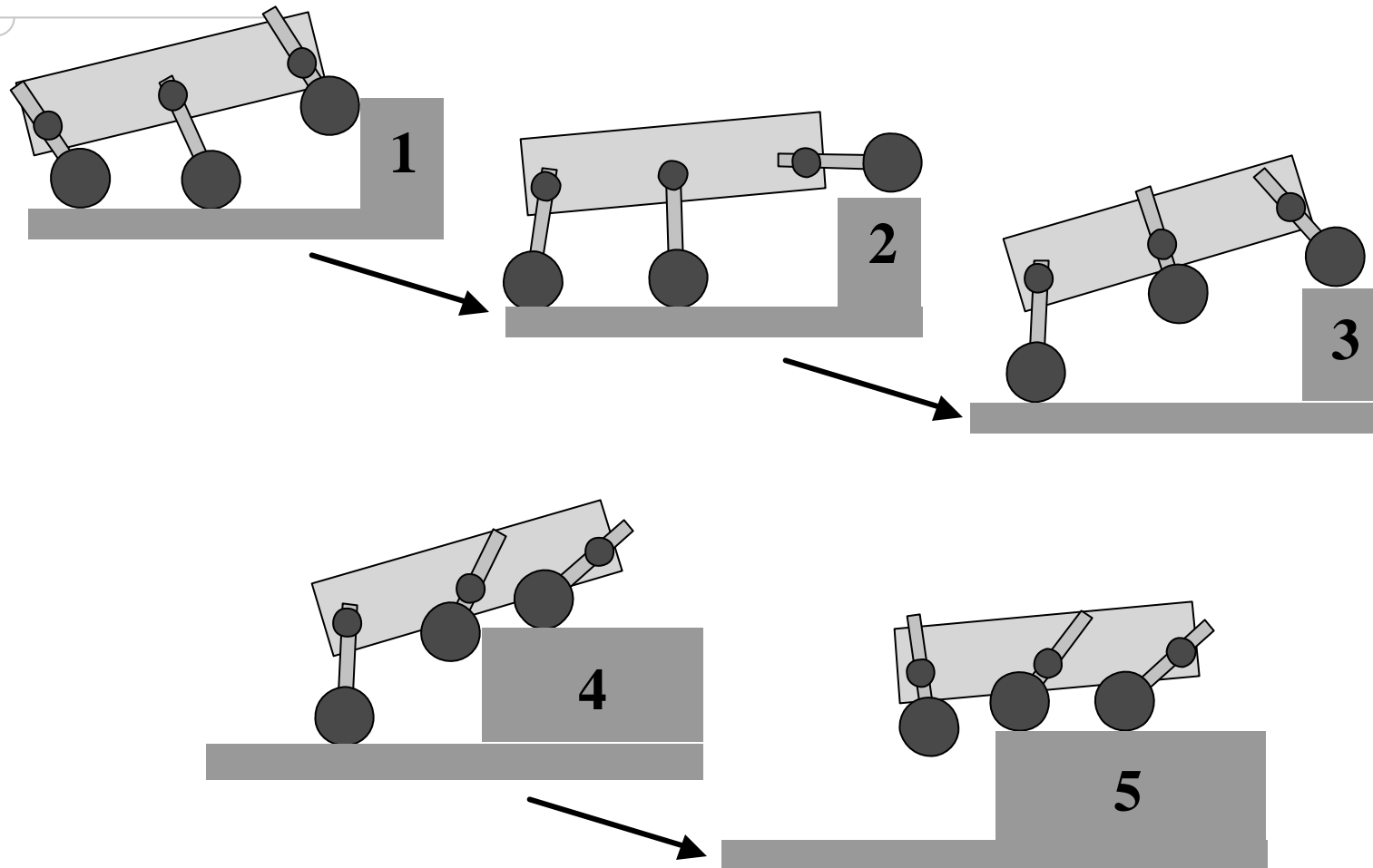
Actuators control 4 degrees of freedom

- In-hub electric drive
- Vertical displacement, damping and adjustable/variable spring stiffness
- Steering
- Tire pressure

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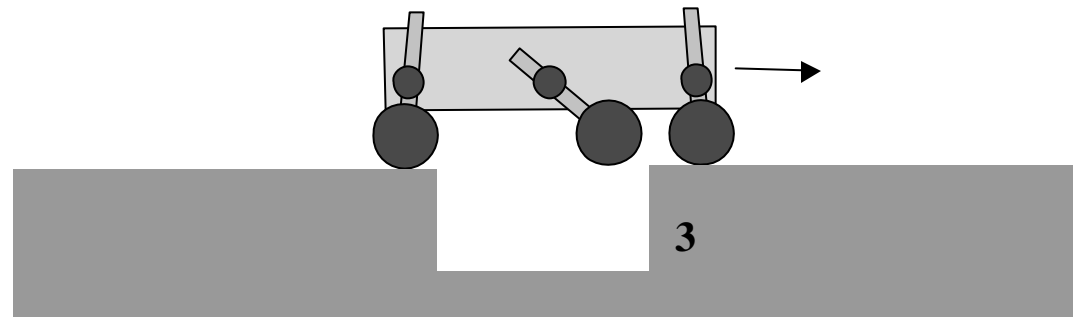
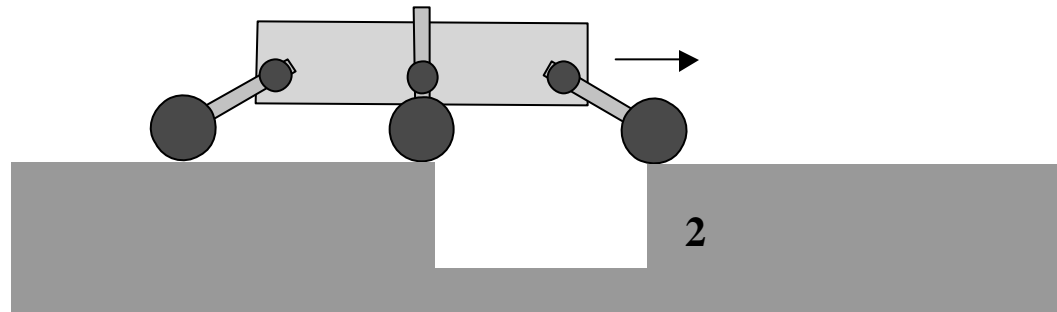
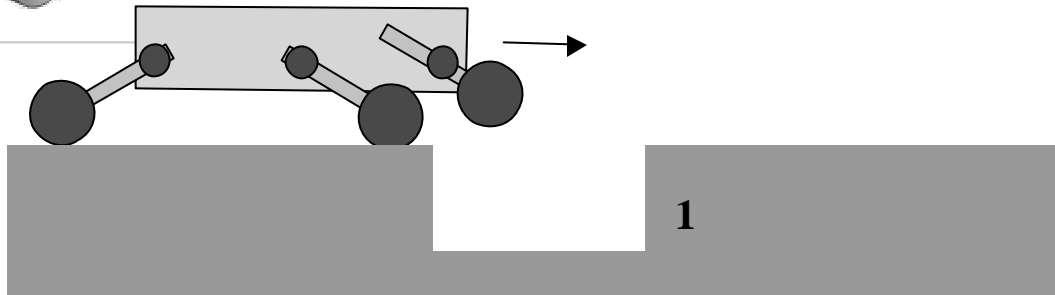
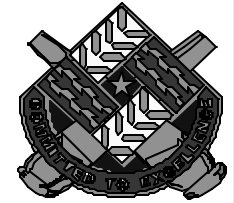
Walking/Climbing Gait for Vertical Obstacles (6-Wheel Drive and 2-DOF Active Suspension)



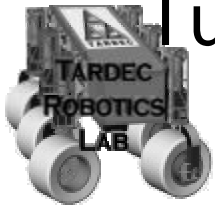
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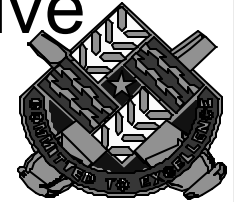
Crevasse Crossing with 2-DOF Active Suspension



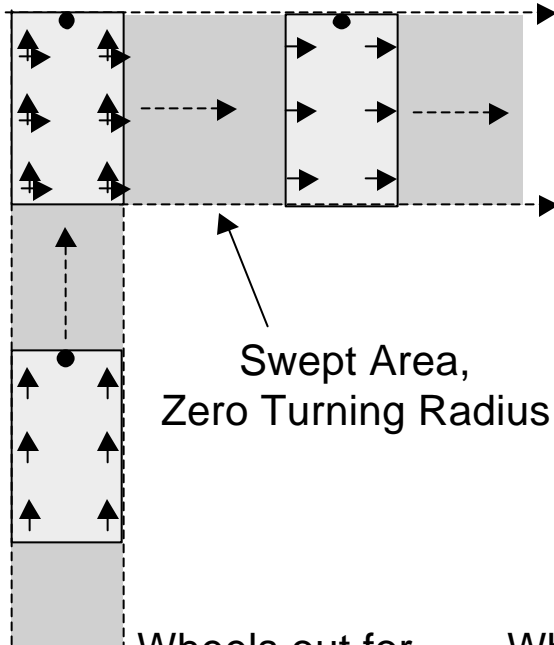
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Turning Maneuvers w/ Omni-Directional Drive (Turning Radius vs. Swept Area Tradeoff)

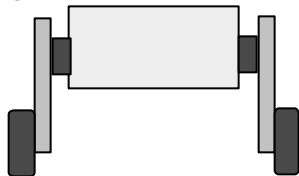


Fixed Body Axis Steering

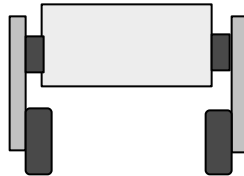


Swept Area,
Zero Turning Radius

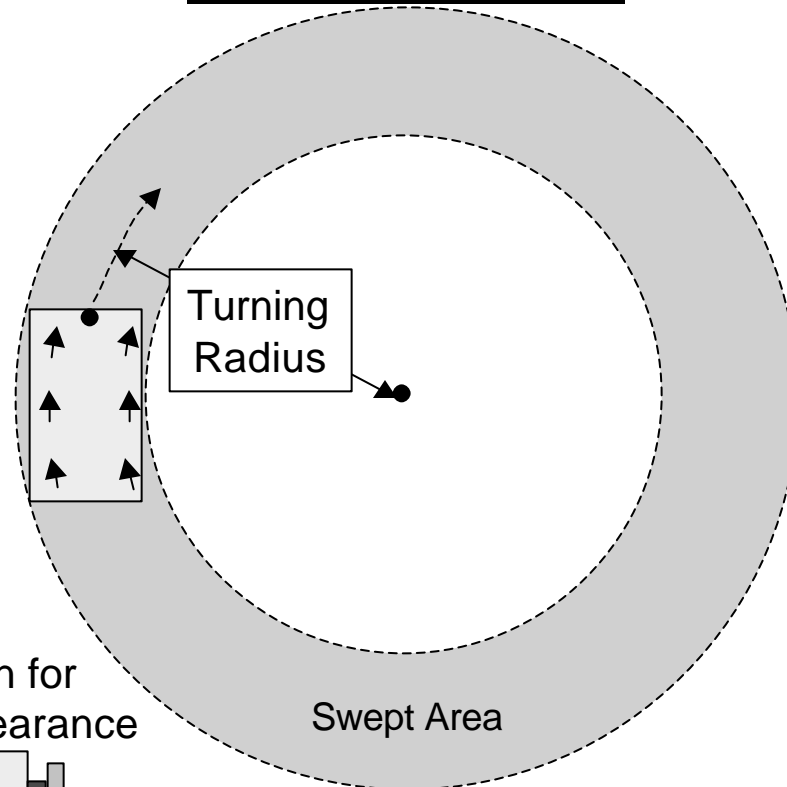
Wheels out for
greater stability



Wheels in for
narrower clearance



Ackerman Steering



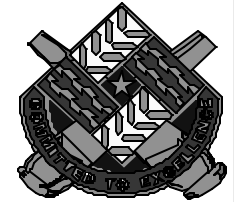
Turning
Radius

Swept Area

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FY01 and Beyond: The Modular Chassis



Chassis has three parts:

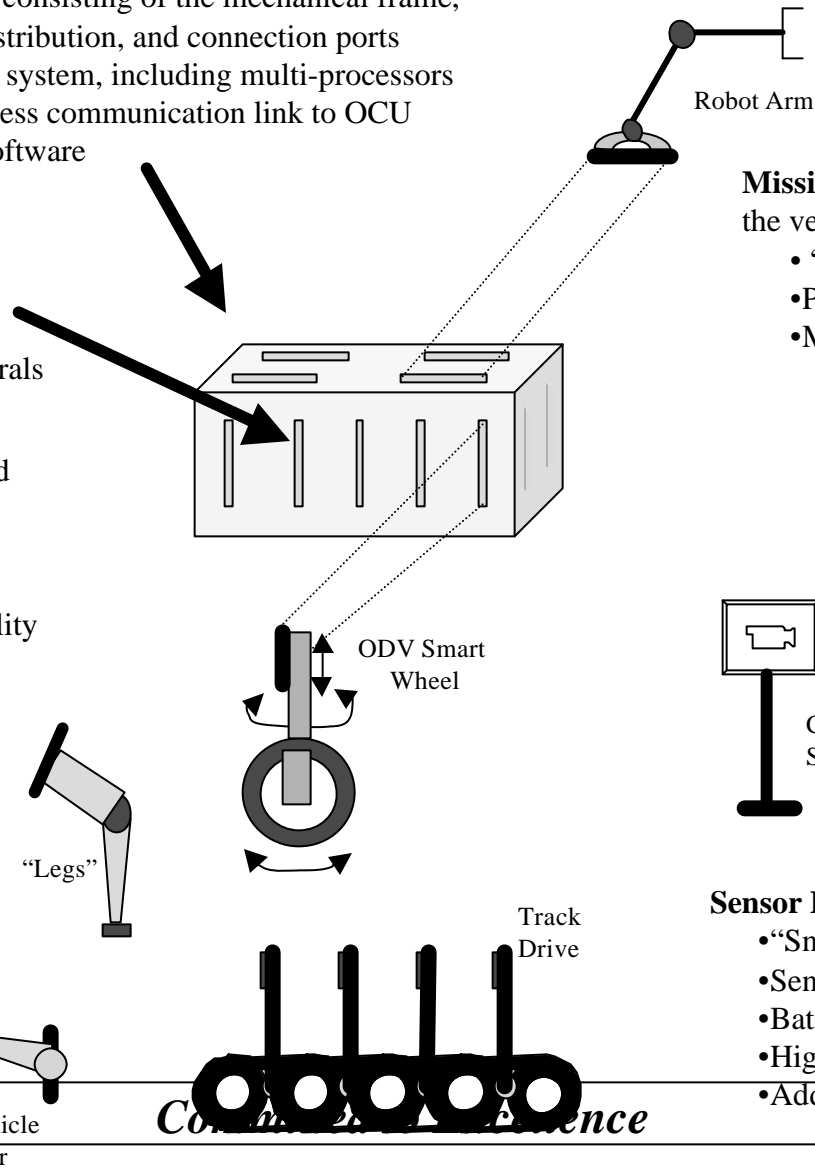
- Core unit consisting of the mechanical frame, power/distribution, and connection ports
- Vetrronics system, including multi-processors and wireless communication link to OCU
- System software

Connection Ports supply

- “Plug and Play” connectivity
- Power to/from peripherals
- Data communications
- Structural support for peripherals

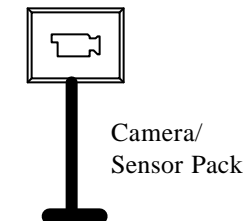
Locomotion Peripherals are used to provide mobility capability

- “Snap and Lock” connections
- Modular system concept
- Deploy a variety of mobility concepts, such as
 - ODV smart wheel
 - Hybrid track wheel
 - “Legs”
 - Fixed wheels
 - Tracks/skid steer
 - Pontoons/propellers
 - Others
- Multi-vehicle coupling



Mission Peripherals provide the vehicle with a reason to exist

- “Snap and Lock” connections
- Provides variety of functionality
- Manipulation concepts such as
 - Robot arms and end effectors
 - Forklift mechanism
 - Explosive ordnance handling
 - Welding fixtures and torches
 - Mission-specific “jigs”

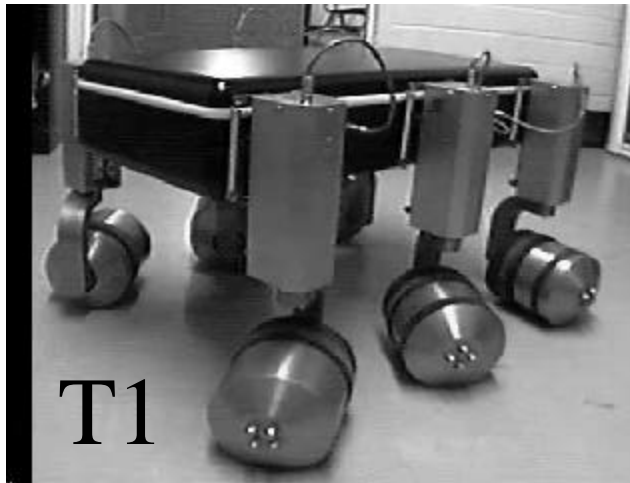
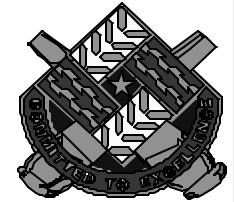


Sensor Peripherals enhance the chassis

- “Snap and Lock” connections
- Sensor packs
- Batteries/generators
- High BW Communications
- Additional computing capability



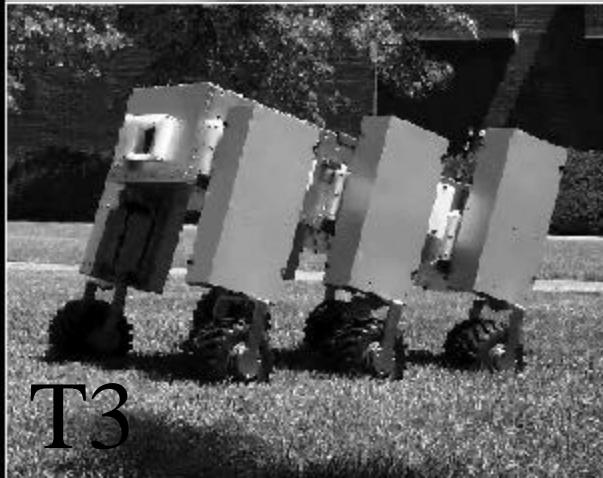
T1, T2, T3, and ODIS



T1



T2



T3



ODIS

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